Torrefied briquettes: technical and economic feasibility and perspectives in the Brazilian market

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This paper presents a study of the impact of introducing a torrefaction system installed in a briquette factory. Cost analysis demonstrates that a briquette factory with a capacity of 1,200 tonnes per year could increase operational profits and reduce the break-even point by 15.7 % by introducing a process to torrefy 60 % of the briquettes produced. Torrefaction, therefore, promotes operational improvement without the need to increase production volume, and the factory becomes a multi-product manufacture, gaining flexibility and competitiveness in markets that are limited or saturated by competitors. This study includes marketing aspects, showing that torrefaction improves briquette quality, enabling access to new possibilities, mainly the domestic market, still unexplored by biomass briquette producers.

1. Introduction

Briquetting is an efficient alternative for utilizing biomass residues [Suárez et al., 2003]. It is a fact, however, that biomass briquettes are not yet widely commercialized in the Brazilian market. Expansion of this market is a technical and marketing challenge, of which the first step is to develop high-quality briquettes. In this sense, torrefaction is an option to improve their quality and, consequently, open up new commercial possibilities.

Briquette torrefaction consists of thermally treating the briquettes at temperatures between 230 and 280ºC in a non-oxidizing environment. In this process the biomass hemicellulose is degraded, maintaining the cellulose and lignin content [Bourgeois, 1984; Doat, 1985]. In this manner, briquettes are converted into a more stable product with higher energy values. Torrefied briquettes have a humidity content of less than 5 %, low emission of volatile substances, fixed carbon between 30 % and 40 % and higher heating value (HHV) in the range of 21 to 23 MJ/kg. Using this process it is possible to obtain gains of as much as 20 % in briquette HHV and conversion yields between 80 % and 90 % as a function of the torrefaction temperature [Felfli, 2003; Pach et al., 2002; Pentananunt et al., 1990]. The torrefied briquettes preserve a large part of the original mechanical properties and can be used in industrial combustion processes, reduction, gasification and as a domestic fuel [Felfli et al., 1999; Girard and Shah, 1991; Lipinsky et al., 2002].

Considering the commercial possibilities that briquette torrefaction offers, in this paper we discuss its technical and economical feasibility in the Brazilian market.

2. Technical and economic analysis

It is possible to make some comparisons of costs and economic indicators when introducing a torrefaction system in a biomass briquette factory.

Figure 1 shows a layout of a high-density briquette (HDB) factory with a capacity to produce 500 kg/h, composed of a biomass grinder (1), a drying silo (2), an exhauster (3), a pneumatic transport system (4), and a screw extruder press (5). The electric power requirement is 103.1 kW and the total investment is R$ 164,500.00. (In February 2005, the exchange rate was 2.60 Brazilian reals (R$) = 1 US$.) Table 1 shows investment requirements (fixed costs) for a biomass briquette factory. Installation costs are considered to be of the order of 10 % of the equipment cost. The useful life is 10 years and we applied a linear depreciation of 10 % a year.

Considering that the factory operates 8 hours a day, 300 days a year, the annual production should be 1,200 tonnes (t). To maintain this level of activity, four workers are needed, which is equivalent to a R$ 30,720.00 annual

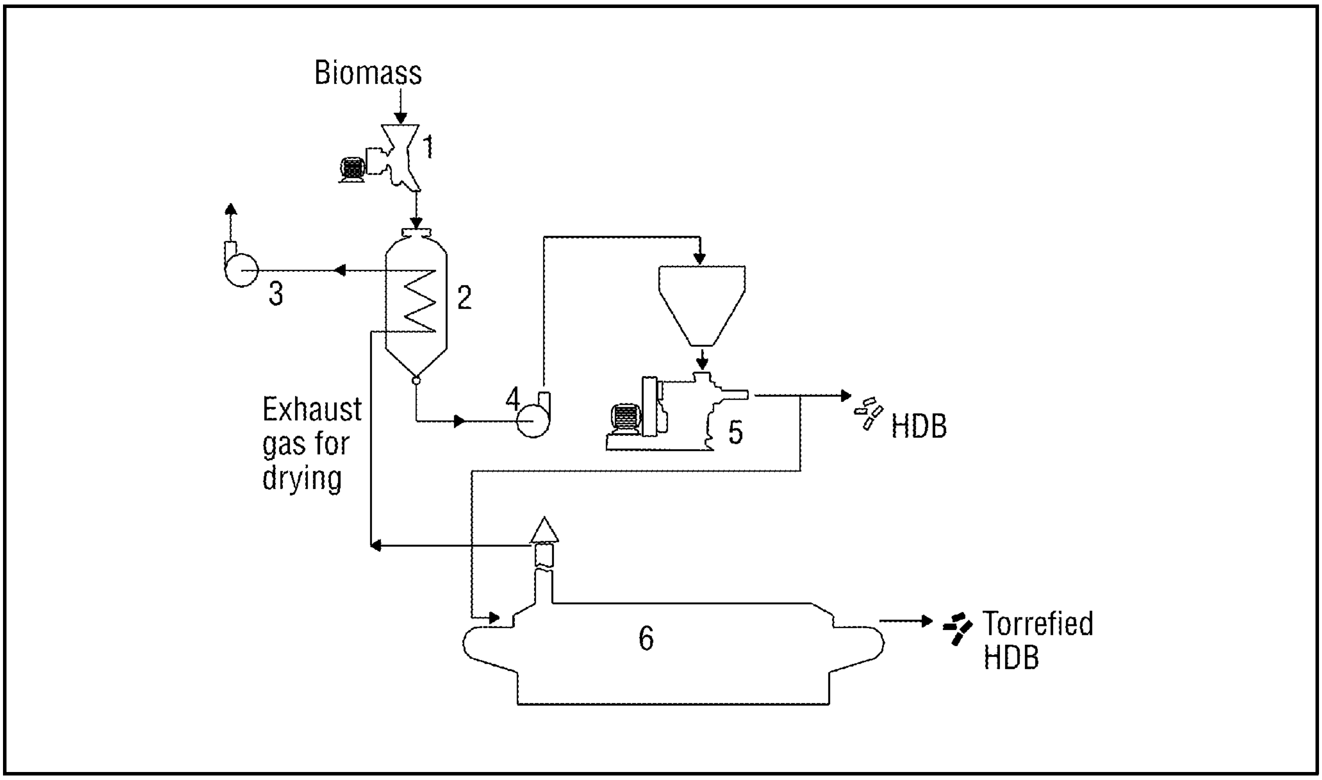

Figure 1. Flowsheet of a briquette factory with a torrefaction system installed.
1, grinder; 2, drying silo; 3, exhauster; 4, pneumatic loader; 5, extruder; 6, torrefactor.

Table 1. Fixed investment[1] for a HDB factory

Asset	Investment (R$)	Annual depreciation (%)	Industrial depreciation (R$/year)
Briquetting equipment[2]	164,500.00	10	16,450.00
Industrial installation[3]	16,450.00	10	1,645.00
Auxiliary equipment[4]	5,000.00	10	500.00
Total	185,950.00	10	18,595.00

Note:

1. Exchange rate: 2.60 R$ = US$ (February 2005)
2. Extruder, grinder and drying silo
3. Installation costs, considered to be 10 % of the briquetting equipment costs
4. Pneumatic loader

payroll, including social and other benefits.

Table 2 shows the structure of the main costs involved in HDB manufacturing. To set up a factory of this size it is necessary to rent a 700 m^2 industrial shed at a market price of approximately 780 R$/month. The expenses incurred in the pre-operational phase (feasibility study, technical and legal assistance, among other things) are estimated to be R$ 5,000.00 and must be amortized at 10 % per year in the operational phase (see the term “amortization of the pre-operational costs” in Table 2) [Machado, 2002; Felfli, 2003].

The cost of biomass residues (raw material) varies between 9 and 16 R$/t as a function of the distance over which they must be transported [Eriksson and Prior, 1990]. For this analysis, the costs considered were R$ 16/t of residue and 5 % of the raw material for the fuel since part of the residue is burnt to produce heat for drying.

Considering the annual costs of the fabrication of HDB and the nominal capacity of the factory, the unitary fabrication cost is 119.70 R$/t. Considering that in Brazil the sale price of briquettes oscillates between 180 and 220 R$/t, the cost calculated is acceptable. The value of the operational break-even point (BE) for the factory can be estimated using Equation 1 [Machado, 2002]:

$$BE = \frac{FC}{OP + FC} = \frac{FC}{GI - VC} \qquad (1)$$

where FC corresponds to annualized fixed costs, VC to variable costs and GI is the annual gross income. The operational profit (OP) and the degree of operational leverage (DOL) may be calculated by Equations 2 and 3 respectively.

$$OP = GI - FC - VC \qquad (2)$$

$$DOL = 1 + \frac{FC}{OP} \qquad (3)$$

At a briquette sale price of R$ 180.00/t, the factory operates with a 48 % BE[1]. Therefore, the volume of minimum profit desired will only be attained after 48 % of nominal production has been reached (Table 3). To reduce the BE, a careful analysis of cost structure is necessary. In this case, the solution may be to look for alternatives that result in lower fixed and variable costs. The increase in sale price is also a possibility to be studied. However, it is important to note that price increase is a limited option since the market itself imposes competitive barriers that can make the increase in price practically ineffective. For example, raising the price from 180 R$/t to 220 R$/t reduces the BE to 35.7 % but can compromise the factory's competitiveness, causing sales to fall and, consequently, the operational BE would be greater than that foreseen.

Analyzing the possibility of operational leverage, we can observe that the degree of operational leverage (DOL) is 1.93[2] (Table 3). This means that a 10 % increase in the factory's activity level will correspond to an increase of 19.3 % in operational profit, that is, the OP would then be R$ 86,306.00 and the BE would be reduced to 43.7 %.

Figure 2 shows trends of the BE and the OP of the factory as the production level increases. Observe that, to obtain a significant BE reduction, the production must be doubled. This is nearly impossible since competition exists and the market is limited. In a more realistic case, it may be possible to increase production by 20 %, depending on market behavior. It is, therefore, a marketing problem and the most feasible solution would be to search for different markets, for example, the domestic market, torrefying a percentage of the briquette production.

The production of torrefied briquettes requires the installation of a torrefaction oven (see Figure 1). Maintaining a nominal production of 1,200 t and considering that 60 % of the production could be torrefied at 280°C, with a yield of 70 %, 504 t of the produced torrefied briquettes (HDB_{280}) could be assigned to domestic consumption (barbecue) and 480 t of HDB would be for consumption in commercial and industrial furnaces.

Table 2. Annual costs of a HDB factory

Costs	R$/year
Fixed costs (FC)	66,926.00
Industrial depreciation	18,595.00
Payment of services rendered & administrative labor	30,000.00
Accountable fees	2,880.00
Amortization of the pre-operational costs	500.00
Industrial shed rent	9,360.00
Industrial equipment maintenance	3,290.00
Other administrative expenses	2,301.00
Variable costs (VC)	76,730.00
Raw materials	**19,200.00**
Fuel	960.00
Industrial labor	30,720.00
Electricity	14,850.00
Packaging	6,000.00
Commercial expenses	5,000.00
Total	143,656.00
Variable unit cost (R$/t):	**119.70**

Table 3. HDB factory indicators

Unit price (R$/t)	GI (R$/year)	OP (R$/year)	BE (%)	DOL
180.00	216,000.00	72,343.50	48.00	1.93

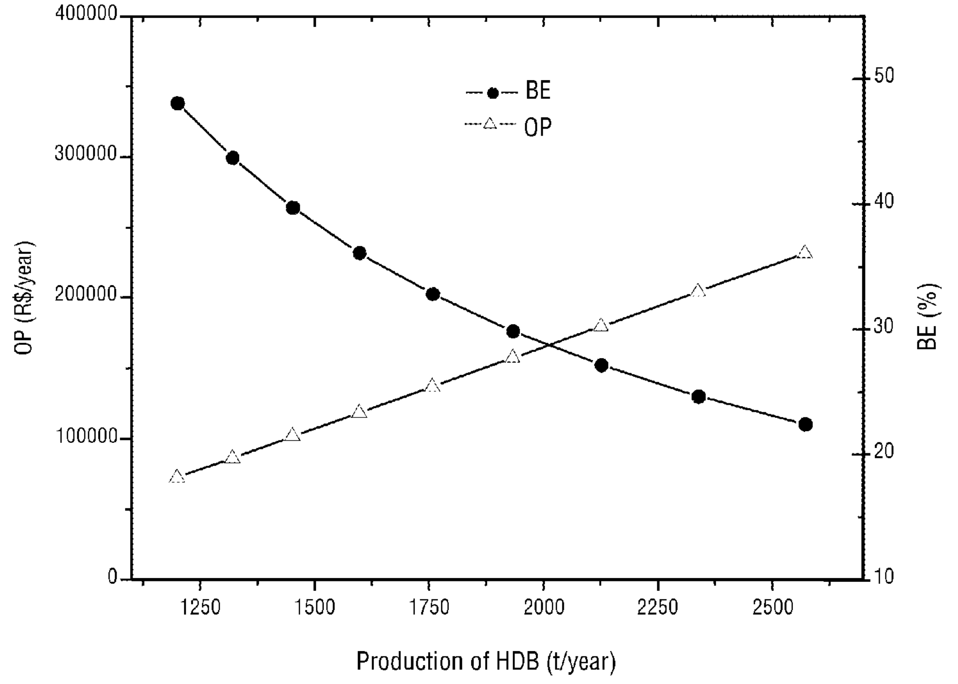

Figure 2. Behavior of OP and BE as functions of the HDB production volume

Table 4. Fixed investment for a briquette factory with a torrefaction system installed

Assets	Investment (R$)	Annual depreciation (%)	Industrial depreciation (R$/year)
Briquetting and torrefaction equipment[1]	214,500.00	10	21,450.00
Industrial installation[2]	21,450.00	10	2,145.00
Auxiliary equipment[3]	5,000.00	10	500.00
Total	240,950.00	10	24,095.00

Notes

1. Extruder, grinder, drying silo, exhauster and torrefaction oven (see Figure 1)
2. Installation costs, considered to be 10 % of the briquetting and torrefaction equipment costs
3. Pneumatic loader (see Figure 1)

Table 5. Annual costs of the briquette factory with a torrefaction system installed

Costs	HDB (R$/year)	HDB_{280} (R$/year)	Total
Fixed costs (FC)	29,390.60	44,085.90	73,476.50
Industrial depreciation	9,638.00	14,457.00	24,095.00
Payment of services rendered	12,000.00	18,000.00	30,000.00
Accountable fees	1,152.00	1,728.00	2,880.00
Amortization of the pre-operational costs	200.00	300.00	500.00
Industrial shed rent	3,744.00	5,616.00	9,360.00
Maintenance	1,716.00	2,574.00	4,290.00
Other administrative expenses	940.60	1,410.90	2,351.50
Variable costs (VC)	34,464.80	51,697.20	86,162.00
Raw material	7,680.00	11,520.00	19,200.00
Fuel	768.00	1,152.00	1,920.00
Industrial labor	15,360.00	23,040.00	38,400.00
Electric energy	6,256.80	9,385.20	15,642.00
Packaging	2,400.00	3,600.00	6,000.00
Commercial expenses	2,000.00	3,000.00	5,000.00
Total	63,855.40	95,783.10	159,638.50
Variable unit cost (R$/t)	133.03	190.05	-

For the new, proposed configuration, the cost of a tunnel-type furnace with a nominal capacity of 500 kg/hr must be added to the cost of the briquetting equipment, increasing investment requirements by R$ 50,000.00 (see Table 4), while operating the torrefaction unit will require an additional worker, increasing the payroll to R$ 38,400.00 per year, including social and other benefits. The factory's power requirements will increase to 108.6 kW. The cost of the fuel was considered to be 10 % of that of raw materials since part of the residues would be burnt to produce heat for torrefaction of the briquettes. To determine the other costs, the same criteria used in the previous analysis were adopted.

Table 5 shows the cost structure of the proposed system. The cost of each single HDB produced with the new configuration is a bit higher than that outgoing from the old system. However, when calculating operational ratios, it is noticed that, after the sale of the HDB_{280} is guaranteed, an internal cost "subsidy" occurs since the factory becomes a multi-product manufacture. The price of charcoal on the retail market is about 1,000 R$/t. The price of the HDB_{280} could then be 450 R$/t on the wholesale market.

Considering the sale of HDB at 180 R$/t and HDB_{280} at 450 R$/t, the gross income is 45 % greater compared to the initial system and the OP is 112 % higher (compare

Table 6. Briquette factory indicators with a torrefaction system installed

Product	Unit price (R$/t)	GI (R$/t)	OP (R$/year)	BE (%)	DOL
HDB	180.00	86,400.00	-	-	-
HDB$_{280}$	450.00	226,800.00	-	-	-
Total	-	313,200.00	153,561.50	32.4	1.48

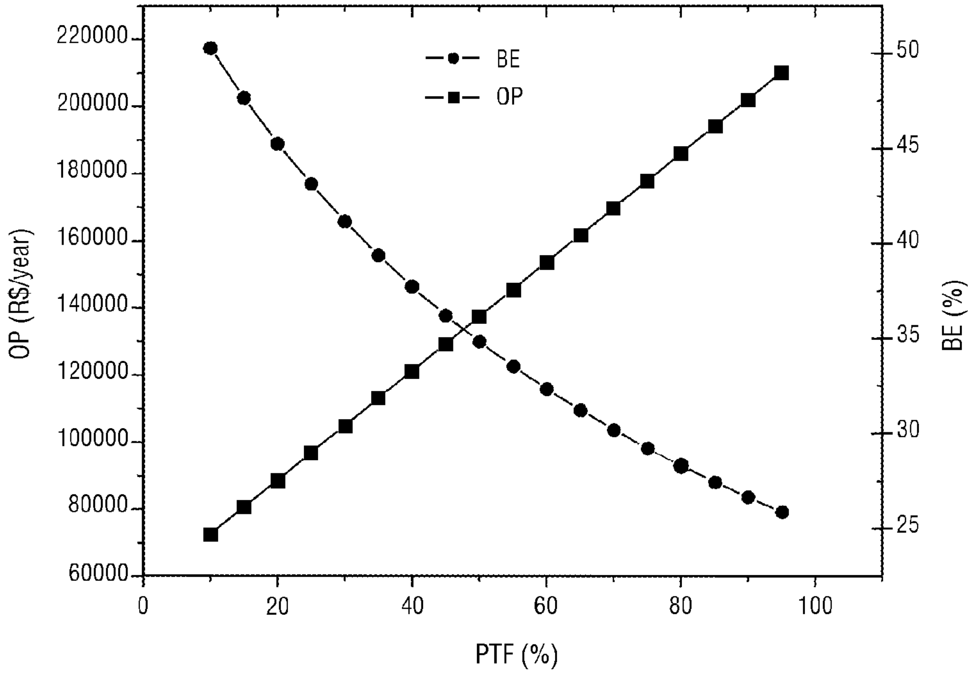

Figure 3. Behavior of BE and OP as functions of the production torrefaction factor

Tables 3 and 6). Consequently, the factory operates with a 32.4 % BE, a reduction of 15.7 % compared to the BE of the initial configuration. Therefore, one can conclude that the introduction of the torrefaction system enables a “leverage” without the need to increase the factory’s production level.

Figure 3 shows both the BE and OP as functions of the product torrefaction factor (PTF – percentage of torrefied briquettes) while maintaining the total production volume. Here it may be noted that the best system operation occurs at elevated levels of PTF. However, the possibility of producing various types of briquettes is the factor that makes the factory more competitive.

3. Perspectives on the domestic market and environmental regulation

Commercial production of torrefied briquettes depends on the scenario of market conditions near the factory to be installed. In the specific case of the domestic market, it may be pointed out that the consumption of charcoal for barbecue is very high among Brazil’s urban population. For example, in the state of São Paulo, 108,360 t of charcoal are produced per year, 64 % of which goes to domestic use, mainly weekend barbecues, and 36 % is consumed by commercial establishments (restaurants specializing in pizza, bakeries, and barbecue). It should be noted that the consumption is larger than production, so it is necessary to import charcoal from other states [Felfli, 2003].

A marketing study directed to domestic charcoal consumers [Felfli, 2003] showed that most users have no preference regarding brands or types. For example, when questioned about the determining factor of the purchase, the majority answered that the main factor was the product’s availability and others were price, quality and origin, as shown in Figure 4.

These results show that competition among brands is practically non-existent, allowing new products to enter the market. The consumers interviewed indicated as main characteristics that charcoal should be of good quality, emphasizing the ease in lighting it, the duration and the

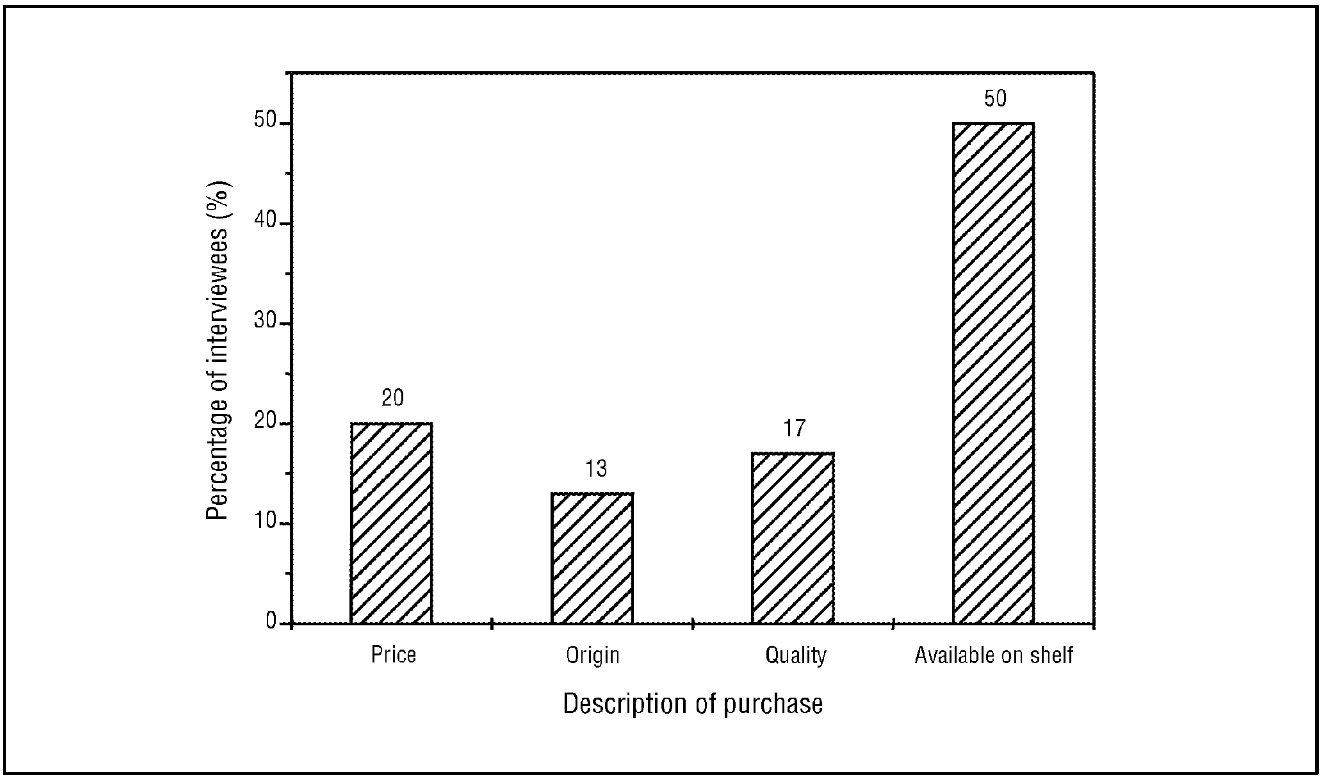

Figure 4. Criteria used by domestic consumers in their decision to buy charcoal

cleanliness during handling. To a greater or lesser degree, all of these qualities can be found in HDB_{280}. Another important aspect is the willingness of 85 % of the interviewees to try new types of charcoal or fuels that are alternatives to traditional charcoal. Considering this fact, it is possible to conclude that torrefied briquettes can be commercialized for domestic consumption as long as they meet consumer expectations.

It is important to mention that the market perspectives for torrefied briquettes and briquettes in general may be even more promising since the environmental demands of national and international entities are becoming increasingly restrictive concerning the use of fuels. For example, in 1991 Sweden created a green tax on the production of energy. This tax is charged as a function of the weight of carbon dioxide emitted by all fuels except bio-fuels and has greatly contributed to promote the Swedish bio-fuels market. Biomass prices have become more competitive in relation to fossil fuels and their use has caused a substantial reduction of carbon dioxide emissions into the atmosphere. The value of this tax is variable depending of the type of fuel, oscillating between 0.023 and 0.068 Eur/t [SVEBIO, 2004].

Since in Brazil a proposed law concerning solid residues is being considered by the National Congress, there are possibilities that a type of incentive for the use of biomass residues in fuels will be instituted, making briquettes more competitive. It is important to note that the use of biomass residues in fuels is an excellent way of avoiding the indiscriminate exploitation of forests for charcoal production by channeling residues from the transformation of wood and agricultural products in an ecologically benign manner. It would be premature to speak of a green tax in Brazil in the next few years. However, a green seal could be instituted for products originating from biomass residues (briquettes, pellets, bio-oils, among others), creating incentives such as a rebate on the "tax on operations relative to circulation of merchandise and services" (ICMS), and facility in obtaining credit and special financing from banks. With the creation of fiscal incentives for commercializing briquettes, more competitive prices would be possible and, consequently, provide incentives for the use of this fuel.

4. Conclusions

The introduction of a torrefaction system in a briquette factory makes production more flexible and competitive. From a technological point of view, it improves the quality of the briquettes, opening up new possibilities for application and, consequently, other markets. It also allows easy adaptation to market demands. By producing different types of briquettes, more than one consumer market can be explored. At the same time, it gives the factory an operational leverage without the need to increase the production level. This is an interesting alternative when operating in markets that are limited or saturated by competitors. This increased efficiency occurs because the factory becomes a multi-product manufacturing facility. So, the operational profit is higher and the break-even point is lower.

From a technical point of view, it is possible to use torrefied briquettes for barbecue; therefore torrefaction is a viable option given local market conditions. A market survey revealed that domestic consumers who use charcoal for barbecues are potential consumers of torrefied briquettes, opening the possibility of expanding the domestic market. ■

Acknowledgements

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Notes

1. From Tables 2 and 3: FC = 66,926.00 R$/year (Table 2); OP = 72,343.50 R$/year (Table 3). Applying Equation (1): BE = 66,926.00 / (66,926.00 + 72,343.50); BE = 0.48 = 48 %
2. From Tables 2 and 3, FC = 66,926.00 R$/year (Table 2). OP = 72,343.50 R$/year (Table 3). Applying Equation (3): DOL = 1+ (66,926.00 / 72,343.50) = 1 + 0.925 = 1.93.

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